



PFC Heat Transfer and Fluid Flow

W Lamellar
C-MOD Tiles

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CFD Model
Li Swirl Flow

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CATIA, FE &
CFD Models

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J. Bullock - *Orion Technologies*
D. Macmahon -

Heat Transfer and Fluid Flow: Other information

- Mod 18 FW Design for ITER – Ulrickson
- Li flows in NSTX and LTX – Ying/Morley/Majeski/Ulrickson
- Be Workshop prior to ICFRM12
- ICFRM12 paper - LANL PS-Be Mockups Tests – Nygren et al.
- PSI 17 abstract on C-MOD W tile testing – Nygren et al.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy under contract DE-AC04-94AL85000.

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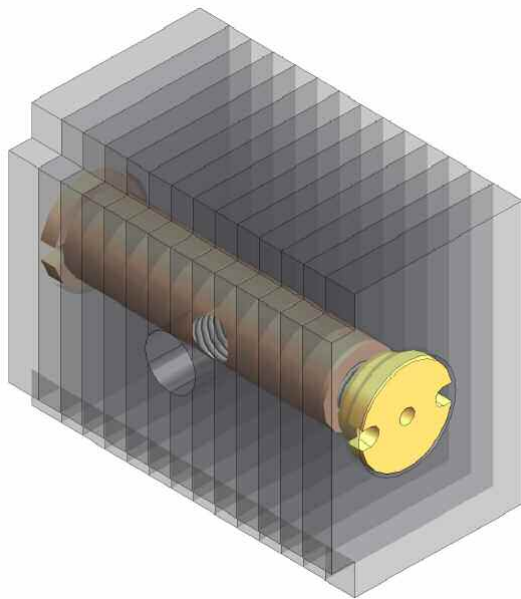
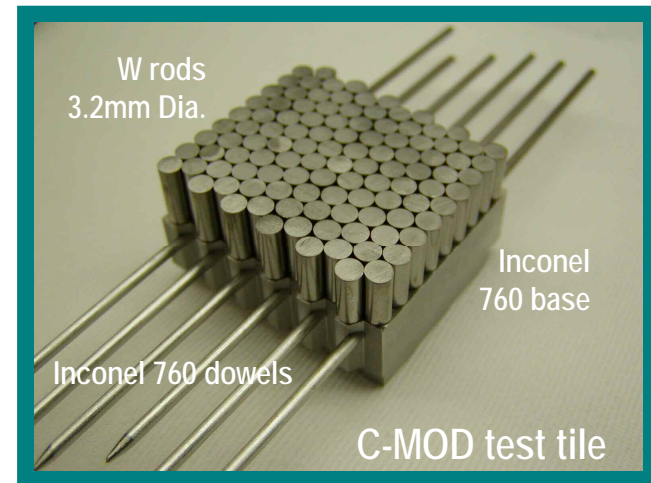


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C-MOD W tiles MIT/Sandia Collaboration

- Last year Sandia tested MIT mockups with “tethered” tungsten (W) rods in EBTS.
- MIT is exploring new designs. One has laminated W plates. MIT sent three W plate tiles for high heat flux tests at Sandia.



The basic objectives were to observe:

- thermal performance (T_{surface} vs q''_{abs}) in 5s shots
- effects of thermal cycles on the heated surface
- effects of thermal cycles on bolt tension

We obtained useful data on thermal performance for all three tiles but melted the Inconel bolts on two tiles before any thermal cycling.

W plate tile HHF test

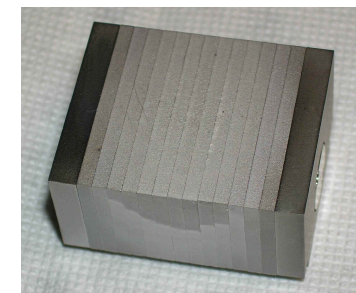
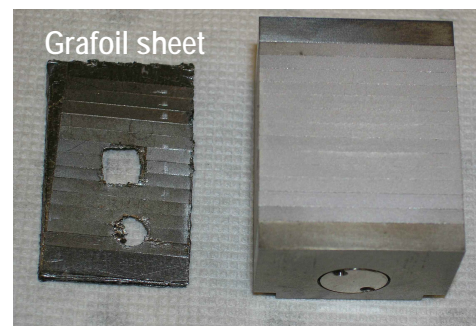
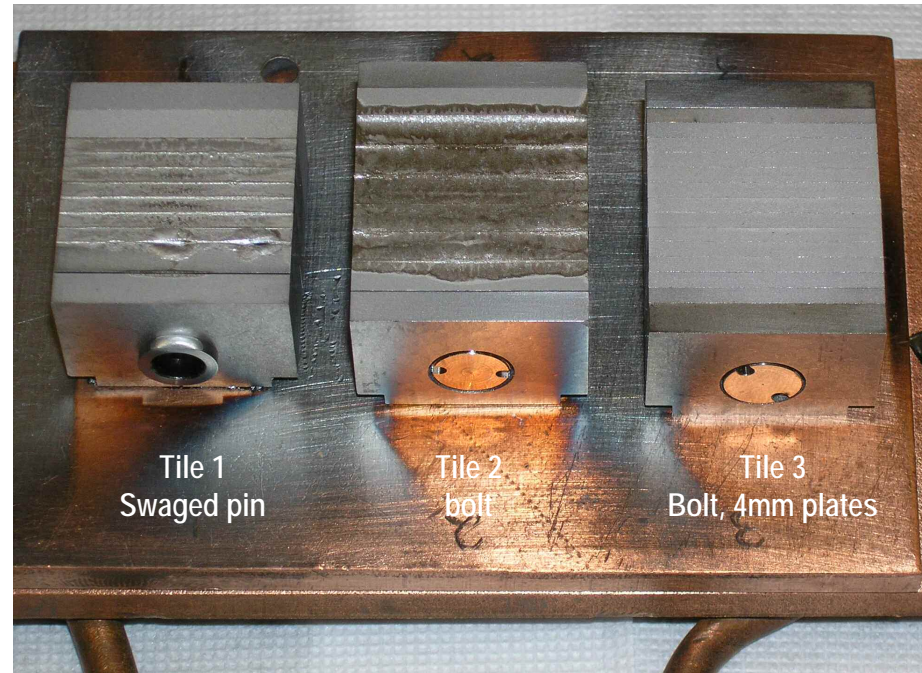
Tile 1 had 2 and 4-mm plates with a swaged hollow pin.

Tile 2 had bolted 2 & 4-mm plates.

Tile 3 had only 2-mm bolted plates, with thicker plates for the ends.

We melted the bolts in Tiles 1 and 2. Melted metal migrated to the heated surface of the tiles. Further testing of these tiles and examination of these surfaces was not useful.

The melting, a consequence of the test procedure, does not imply that the bolt/plate configurations of these tiles are inferior to that of Tile 3.

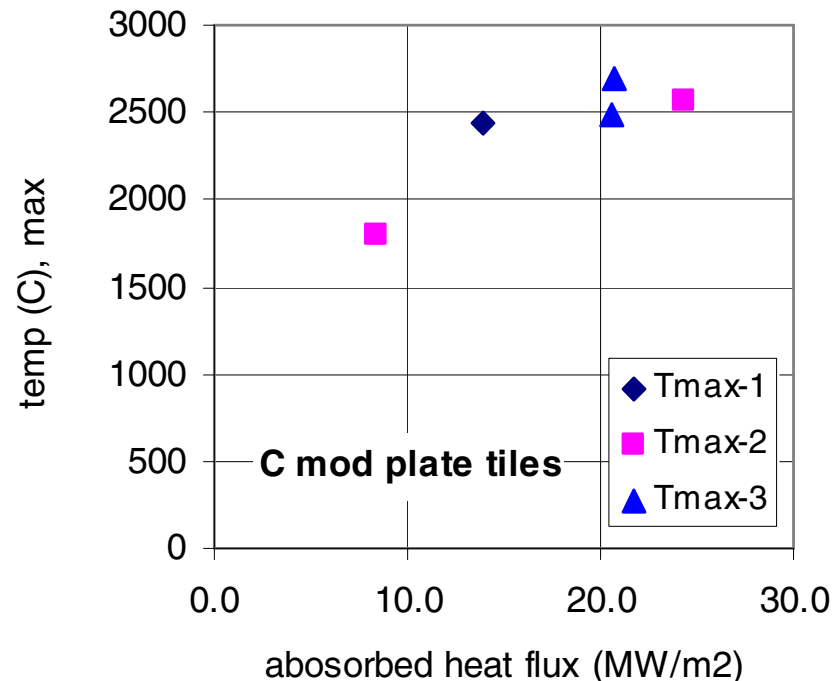


W plate tile thermal performance

The maximum surface temperatures of the tiles (from pyrometer data) versus the absorbed heat load during 5 s shots is shown here.

The maximum temperature of the bolts was not measured directly and is a critical aspect of the response of the tiles and the robustness of the design.

Use of thermal analyses to compare with the test data may help estimate the temperatures of the bolts, but with some assumptions about the thermal contact.

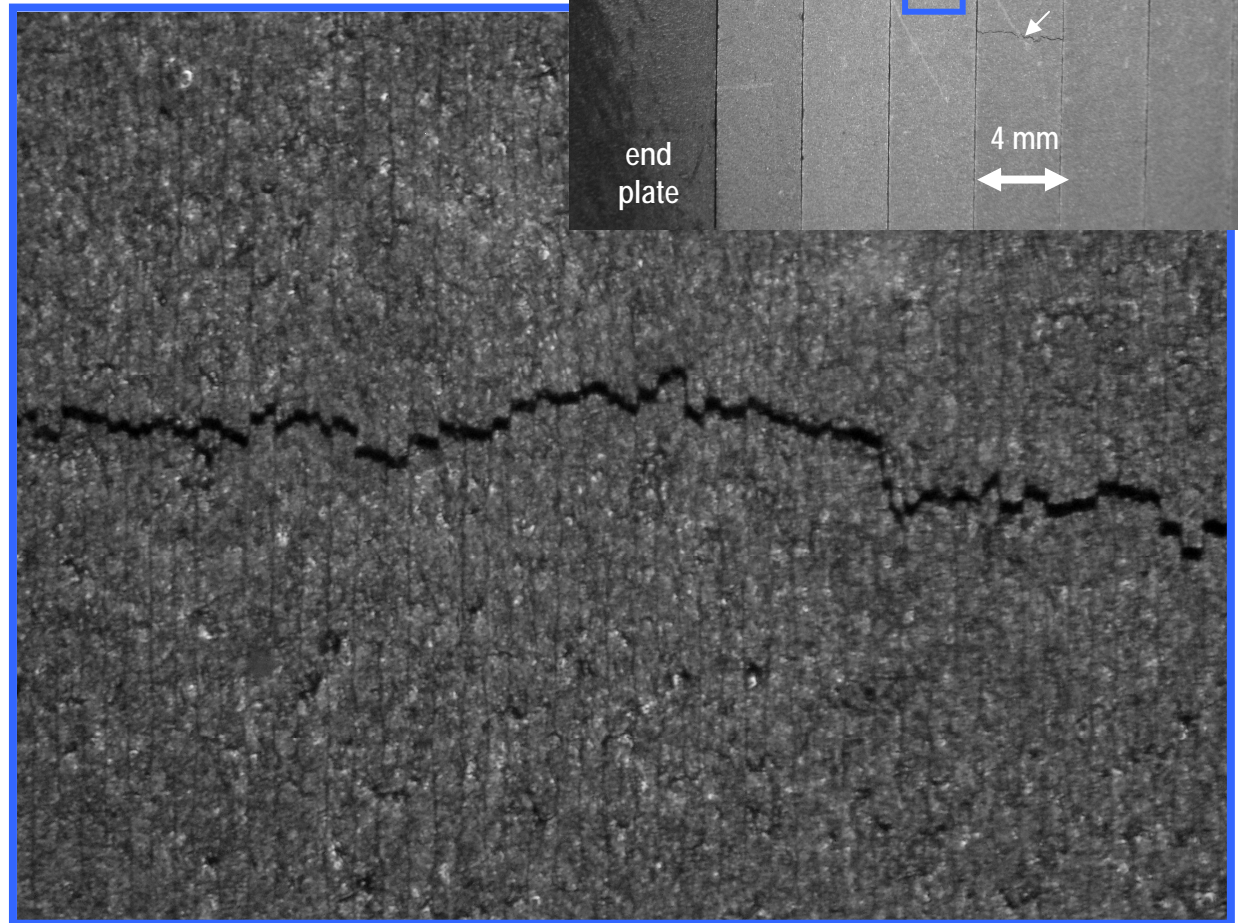


MIT is investigating options for (bolt) materials with acceptable strengths at a higher temperature than the capability of Inconel 625. ?TZM or W-Re; Ta and Nb form hydrides.

W plate tile post-test exam

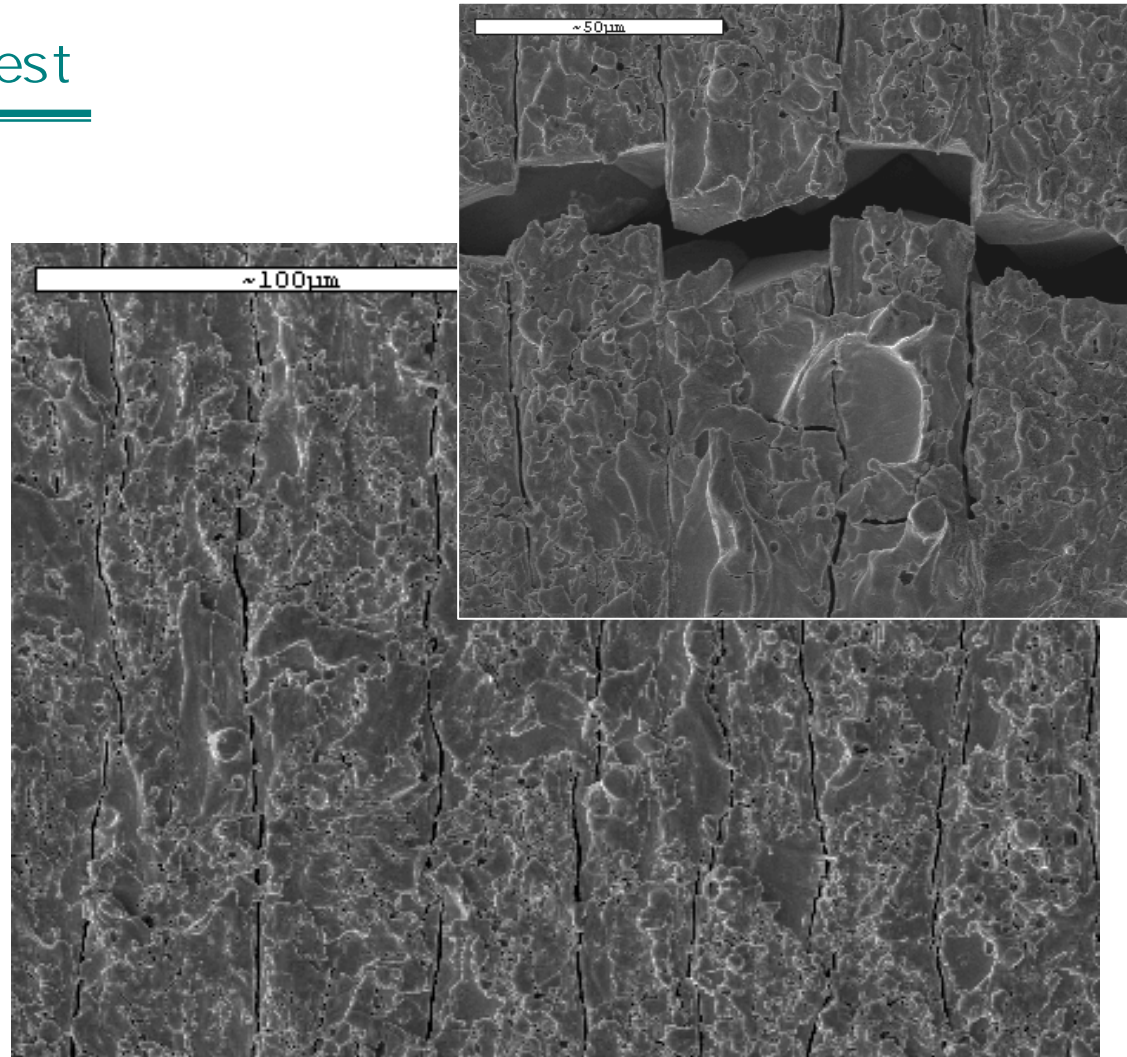
The heated surface of Tile 3 had three transverse cracks in one plate and two in another.

All plates had a pattern of surface cracks parallel to the plane of the plate. The parallel surface cracks had a very regular spacing.



W plate tile HHF test

“Jogging” intersections of a transverse crack with the parallel cracks suggests the parallel cracks formed first. Then, as a transverse crack grew to the next intersection, it jogged along the preformed parallel crack paths.



Concluding Remarks

- MIT continues to explore the application of tungsten (W) tiles in C-MOD. They developed designs with 2 & 4-mm thick lamellar plates bolted together.
- Sandia tested three tiles and obtained data on their thermal performance. We melted the Inconel bolts on two tiles before any thermal cycling could be done. Limited thermal cycling was done on one tile (Tile 3).
- Optical and SEM examinations showed a few transverse surface cracks (across the thickness) in the 4-mm plates in Tile 3 and rather fine uniform cracking in the heated surface parallel to the plane of the plates.
- Ion milling of Tile 3 is also planned to observe the grain structure on the plane perpendicular to a pattern of fine surface cracks.
- MIT is concerned about the robustness of this tile design with respect to melting of the bolts and is investigating other materials.